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## INTRODUCTION

We considered the effect of extensive forces on dust grains subjected to the light and matter distribution of a spiral galaxy (Greenberg et al. (1987), Ferrini et al. (1987), Barsella et al. (1988), hereafter Paper I). We have shown that the combined force on a small particle located above the plane of a galactic disk may be either attractive or repulsive depending on a variety of parameters. We found, for example, that graphite grains from 20 nm to 250 nm radius are expelled from a typical galaxy, while silicates and other forms of dielectrics, after initial expulsion, may settle in potential minimum within the halo. We have discussed only the statical behaviour of the forces for 17 galaxies whose luminosity and matter distribution in the disk, bulge and halo components are reasonably well known.

We present here the preliminary results of the study of the motion of a dust grain for NGC 3198, the same galaxy we have discussed in Paper I.

## THE MODEL

The forces present in the equation of motion are:

### (a) - Gravitation

The force on a dust grain of mass  $m_g$  may be written:

$$\vec{F}_G(\vec{r}) = m_g \vec{G}(\vec{r})$$

where  $\vec{G}(\vec{r})$  is the gravitational field intensity at the point  $\vec{r}$ .

### (b) - Radiation pressure

The force on a grain of radius  $a$  and radiation pressure coefficient  $Q_{pr}(a, \nu)$  is:

$$\vec{F}_R(\vec{r}) = \pi a^2 \int d\vec{\rho} \int d\nu Q_{pr}(a, \nu) \vec{\Psi}(\vec{r}, \vec{\rho}, \nu)$$

where  $\vec{\Psi}$  is the radiation field due to a small portion of the galaxy at  $\vec{\rho}$  on the grain at position  $\vec{r}$  at frequency  $\nu$ . We assume that the luminosity function of the galaxy may be splitted into two parts: a global luminosity function, depending on the galactic position, and a spectral function, which depends only on the Hubble type of the galaxy. Hence the radiation field function may be written:  $\vec{\Psi}(\vec{r}, \vec{\rho}, \nu) = \vec{\Xi}(\vec{r}, \vec{\rho}) \Omega(\nu)$ .

To perform the integration over  $\nu$ , we adopt the spectral energy distribution for Sc type galaxies as given by Pence (1976) and Yoshii and Takahara (1988).

(c) - Gas drag

The drag force exerted by the gas is:

$$F_{gas} = 2\pi a^2 n k T \left\{ \left( s^2 + 1 - \frac{1}{4s^2} \right) \operatorname{erf}(s) + \left( s + \frac{1}{2s} \right) \frac{e^{-s^2}}{\sqrt{\pi}} \right\}$$

$$s = \left( \frac{m_H v^2}{2kT} \right)^{\frac{1}{2}}$$

where  $v$  is the grain velocity,  $T$  is the temperature of the gas and  $n$  is its number density (see Draine and Salpeter (1979)).

We assume that the gas in the region outside of the galactic disk is composed of atomic hydrogen with an exponentially decreasing number density  $n$  and a pressure  $p/k = nT$  also described by an exponential function with a scale length comparable to the thickness of the halo gas. This stratified structure of the gas in the halo may be changed in the equations of motion by specifying the density and pressure scale lengths, the density and the temperature at the edge of the disk, and the thickness of the gas halo. As a guide, we have adopted the scheme proposed by Savage (1986):

$$n \approx 0.5 \text{ cm}^{-3} \text{ at 100 pc}$$

$$T \approx 5000 \text{ K at 100 pc}$$

and we have assumed a thickness of the gas halo equal to one tenth of the galactic halo radius.

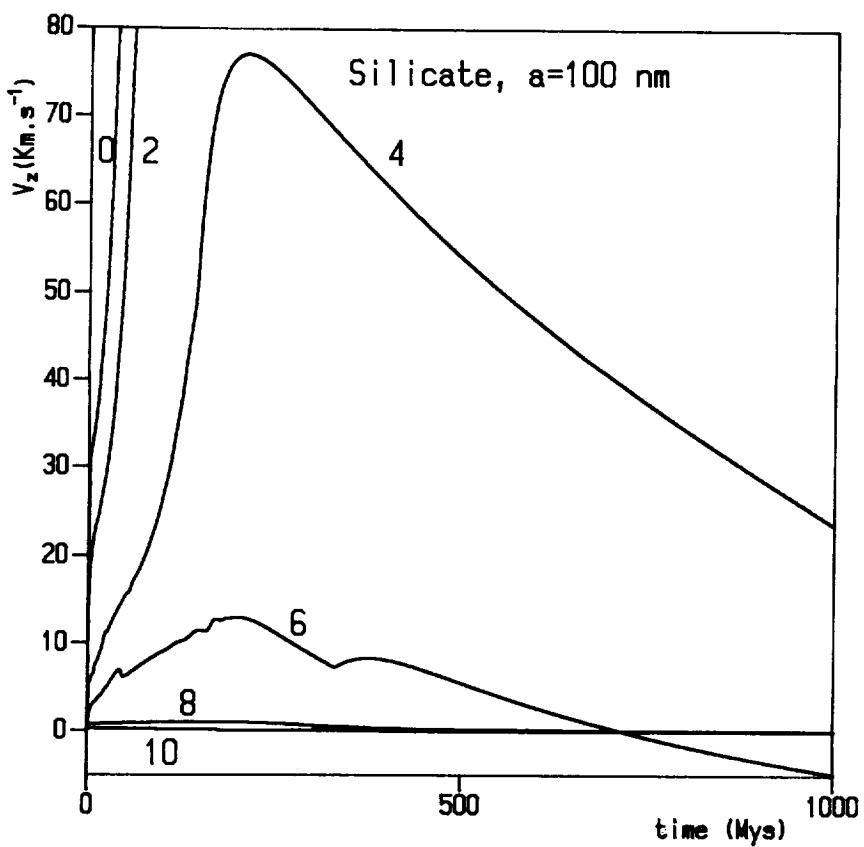
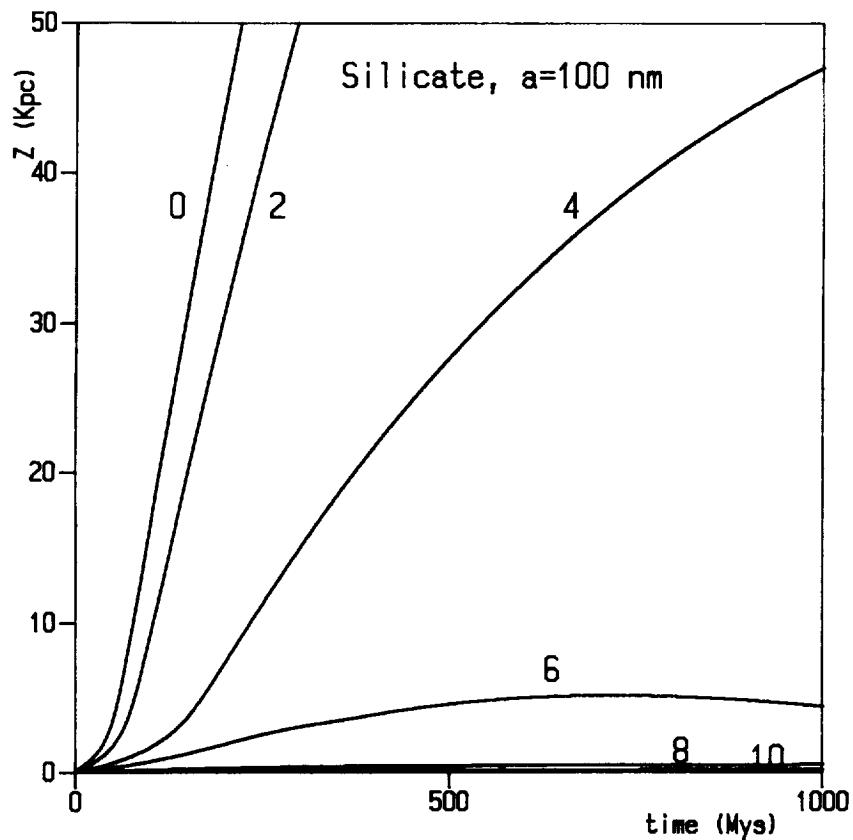
The system of ordinary differential equations that describes the motion of a dust grain has been numerically solved with Livermore Solver for Ordinary Differential Equations (LSODE).

## RESULTS

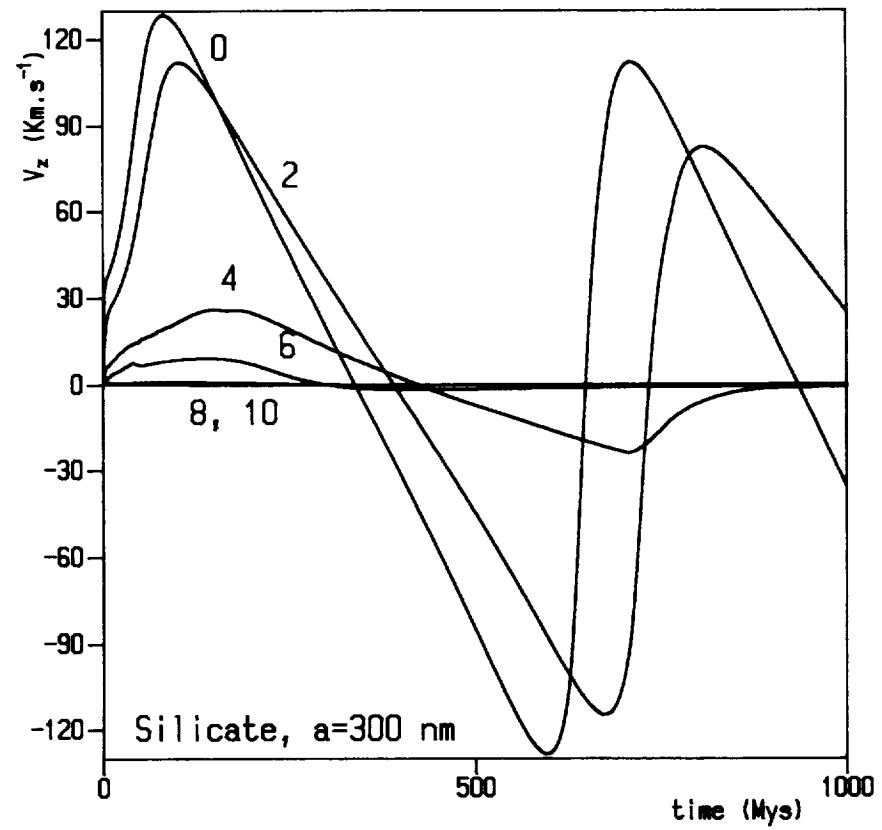
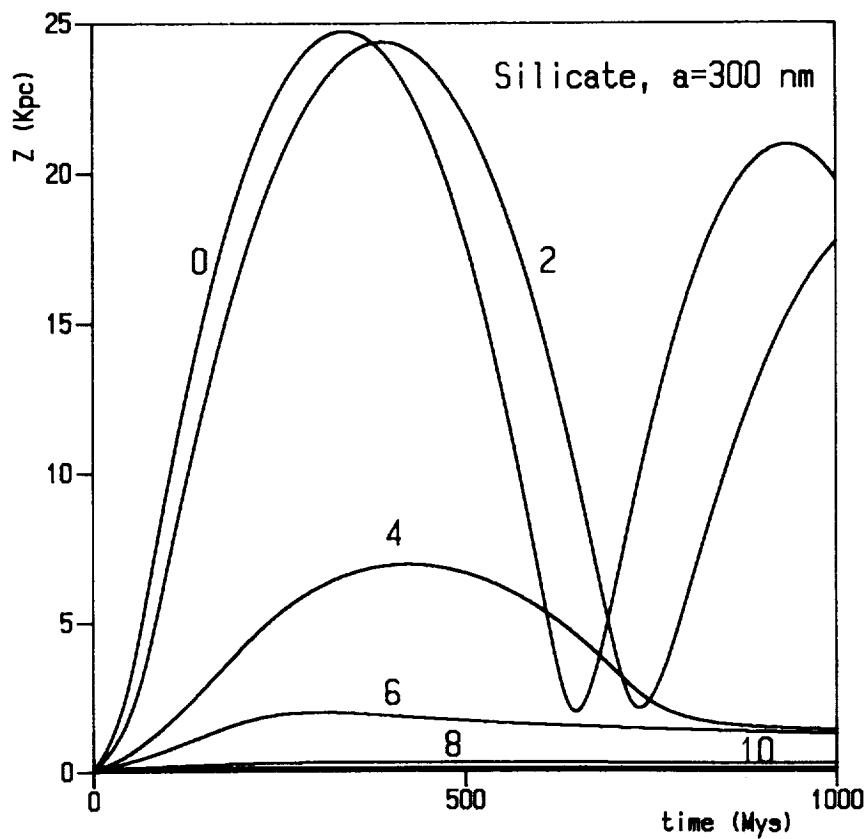
We have solved the equation of motion for single grains in some selected cases. The galaxy we have chosen was the same of Paper I (NGC 3198), a "typical" galaxy. Our preceding static analysis of the forces had lead us to select, for this preliminary study, only astronomical silicate grains of intermediate radii (in particular  $a = 100, 200$  and  $300$  nm).

The initial conditions we have chosen are: starting point 100 pc high on the galactic plane of symmetry; galactocentric radii:  $0, 2, 4, \dots, 10$  kpc, initial velocity equal to the rotational velocity of the galaxy at that position as measured from 21 cm observations of HI. We have integrated the equations of motion with a display step of 2 Myr for a total integration time of 1 Gyr.

The results are presented in Figures 1,2 3 and 4. The most interesting results are the following:



Figs. 1 and 2 –  $z$  position and  $z$  component of the velocity, as a function of time, for a grain of astronomical silicate of radius  $a = 100$  nm (The numbers on the lines represent the starting distance in kpc).



Figs. 3 and 4 – z position and z component of the velocity, as a function of time, for a grain of astronomical silicate of radius  $a = 300$  nm (The numbers on the lines represent the starting distance in kpc).

- ~~the expulsion is effective~~, in this case, only for grains of radii  $a = 100$  and  $200$  nm. In addition, the region of ~~the galactic plane where the expulsion may take place is limited to about half of the luminosity radius, which for NGC 3198 is about 10 kpc.~~
- the time scale for crossing the hot gas region is dependent on the galactocentric distance and on the grain radius, and is approximately  $8 \div 15$  Myr for  $a = 100$  nm and  $20 \div 30$  Mr for  $a = 200$  nm. This means that the grain may suffer considerable erosion in the hot medium; this effect must therefore be introduced in the model. In any case, these time intervals are not larger than the life-time for destruction of the grain by sputtering ( Draine and Salpeter (1979)), and therefore a certain amount of dust may be expelled. A careful analysis of the size evolution of the grain may give an idea of the metallicity increase of the diffuse halo gas due to this mechanism.

## ACKNOWLEDGEMENTS

As we have said before, the solution of the system of differential equations of motion has been done using the LSODE package . Thanks are due to A. Hindmarsh who has written it and to J. Dongarra who has put it on the networks.

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